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GIS INTEGRATION METHIOD FOR GEOTHERMAL POWER PLANT SITEING IN SABALAN AREA, NW IRAN

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ABSTRACT

Geographic Information System (GIS) was used as a decision-making tool to target potential geothermal power plant sites in Sabalan geothermal field, northwestern part of Iran. The aim of the study was to identify suitable areas to establish 55 MW geothermal power plants (GPP).

After comprehensive study about required data for GPP site selection project, available data in the area on a regional scale (1:25000) were categorized in three datasets; Physical (slope, hydrology and faults), socioeconomical (population centers, land use and access roads) and technical (anomaly area, wells pad locations and hot springs).

A knowledge-driven Boolean integration method within a Geographical Information System was used, to determine the spatial association between physical, socioeconomical and technical evidences to determine potential geothermal power generation sites. ArcMap, consisting of geoprocessing and model building tools was used to run the GIS Model for Geothermal Power Plant (GM-GPP) site selection project. Finally, 7 suitable sites, around 1% of the study area were selected.

Keywords: Iran, GIS, Sabalan, Site selection

INTRODUCTION

Geothermal energy offers a number of advantages over traditional fossil fuel based sources. From an environmental standpoint, the energy harnessed is clean and safe for the surrounding environment. It is also sustainable because the hot water used in the geothermal process can be re-injected into the ground to produce more steam. In addition, geothermal power plants are unaffected by changing weather conditions. In countries where many resource alternatives are available for power generation, geothermal has been a preferred resource because it cannot be transported for sale, and the use of geothermal energy enables fossil fuels to be used for better purposes. Moreover, geothermal plants can be built much more rapidly than plants using fossil fuel but there are several environmental concerns behind geothermal energy. Construction of the power plants can adversely affect land stability in the surrounding region. This study by using site selection technologies and considering GPPs requirements is looking for stable sites with minimum impacts on surrounding environment and maximum economic benefits for developers.

In this study ArcGIS was used as an effective tool for the integral interpretation of geoscientific data using computerized approach. This approach has been used to determine GPP sites by combining various digital data layers in Sabalan geothermal field NW Iran. These data were categorized in three datasets; Physical (slope, hydrology and faults), socioeconomical (population centers, land use and access roads) and technical (anomaly area, wells pad locations and hot springs).

The model builder tools in ArcGIS were used as a graphical environment to develop a diagram of the multiple steps required to complete complex geoprocessing tasks to determine the spatial association between physical, socioeconomical and technical evidences to determine potential geothermal power generation sites.

STUDY AREA

The Sabalan geothermal field is located in northwest part of Iran and study area is 282 km^2 including Khiav River watershed located in east.

It is located between 38° 12' and 38° 22’ North and 47° 39’ and 47° 49’ East. Villages Moeil, Valezir, and Dizo are population centers located approximately 16 km main road which connects Meshkinshahr city to Moeil.

Sabalan Mt. is the 29th highest mountain in the world and a quaternary beautiful volcanic complex that rises to a height of 4811 m above sea level located in southeast. The study area is remote, covered by intensive grass and full of hot and cold springs. The location of the study area is shown in Figure. 1.

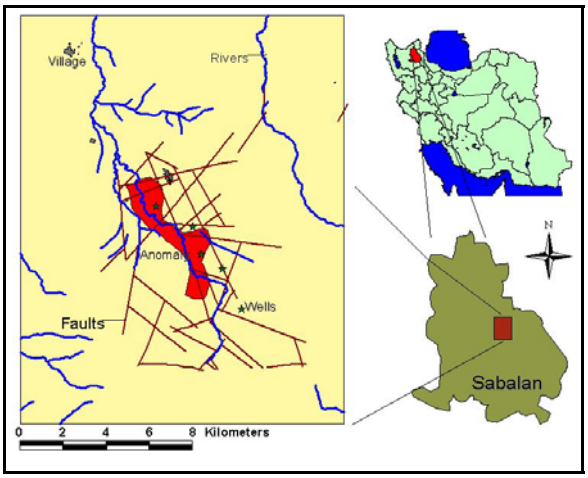

Figure. 1. Study area

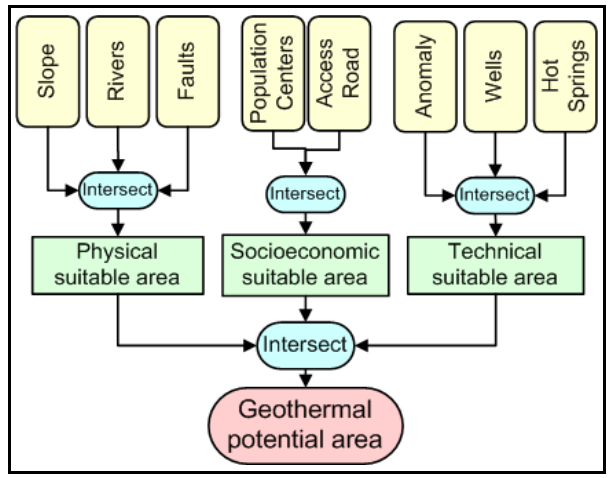

Figure. 2. The schematic of GPP siting method

METHODOLOGY

A GIS was used to carry out a suitability analysis and site selection process because it can handle a large amount of data, is a powerful tool to visualize new and existing data, can help produce new maps while avoiding human errors made during decision-making and allows the effective management of the GIS data (Noorollahi et al., 2007). Boolean intersect analytical method was used for selection queries. This method is described briefly in the following section.

This study was carried out in the1:25,000 scale and 8 important required data layers are employed. In every made factor map the study area was classified into two classless; suitable or non-suitable and binary maps were generated. These operations can be represented by the following simple equation (Noorollahi et al, 2007): (1)

$$SA = (F \cap Ri \cap S) \cap (PC \cap AR) \cap (A \cap W \cap HS)$$

where the $\cap$ is "AND" operations, Sa is suitable areas and F, Ri, S, PC, AR, A, W, HS are Faults, Rivers, Slope, Population Centers, Access Roads, Anomaly zone, Wells and Hot Springs, respectively. A diagram of the method that was used in the decision-making process is illustrated in Figure. 2

Intersecting Method (AND operation)

The Intersect tool in ArcInfo calculates the geometric intersection of any number of feature classes and data layers that are indicative of geothermal activity (e.g., elevated temperature gradients, surface mapped alterations, etc.). Features that are common to all input data layers are selected using this method (Bonham-Carter, 1994). This implies that the selected area is suitable for the purpose of a study based on all input data layers, and the selected area receives the highest suitability ranking.

EVIDENCE LAYERS

The suitable areas for GPP in NW Sabalan area were identified by using available digital data layers categorized in three datasets including physical, socioeconomic and technical. Each dataset includes some data layers. These data layers were used to make factor maps and factor maps were applied to the GM-GPP process. The data layers introduced in the model are spatial distribution of slope, rivers, faults, population centers, access roads, anomaly zone, wells location and hot springs (Figure. 3).

Physical dataset

Physical studies play an important role in all stages of GPP siting. In the initial stages of siting programs, the study areas were typically studied together, with one being chosen for detailed investigation (Rybach and Muffler, 1981). Physical studies also provide background information for interpreting the data obtained using other siting methods. Physical information can also be used in the production stage for other developments and management. The duration and cost of development can be minimized by physical siting program.

Slope

Slope refers to how steep the surface of the land is. Steep slopes are a limitation for GPP development, not only because of the cost and transportation but also water that can find pathway from the drain to flow on the surface. Basically the slope limitations for any development are slight if the slope is less than 8%, moderate if the slope is 8-15% and severe if the slope is greater than 15%.

In this study, topography counters map of the study area was used to create a slope binary factor map to use in the GM-GPP process (Figure. 3). To identify suitable areas based on slope data, study area was divided into two features; less than 15% and more

than 15% of slope. The areas with the slope of less than 15% were totally 149 km^2 which were selected as suitable areas for GPP based on slope evidence.

River

River limitations refer to the location of rivers and potential for flooding by streams or rivers around GPP in the study area. On the other hand, the area without river, stream or big tributary drainage with their buffer can be assumed as a suitable area for GPP based on the river.

There are 82 km river in the study area. 47 km of these rivers which is called khiav river, is a beautiful river, runs north from Mt. Kasra, between the two villages of Moeil (to the east) and Dizo (to the west), to meshkinshahr city on the middle of wide Darreh Rud valley had a calcium-magnesium hardness of only 80 mg/l and temperature 7.5°C (Figure. 3).

This valley has 120-280 meter depth that surrounded by steep slope, therefore the selected area in the West side of the river were not selected because plumbing geothermal fluid from the wells which all located in the East side of the river is not economic.

In this study, 200 m buffer size was given around the rivers features in data layer to identify river limitation areas. The areas beyond this limitation were selected as suitable area for GPP based on the river.

Faults

In geology, faults are discontinuities (cracks) in the earth's crust that have been responsible for many destructive earthquakes.

Blewitt et al. (2003) indicated that at a regional scale, geothermal plumbing systems might be controlled by fault planes. Therefore fractures and faults play an important role in geothermal fields, as fluid mostly flows through fractures in the reservoir rocks.

In the current study for avoiding of risk-taking of faults, 200 meter buffer size was applied by using the ArcMap Buffer tool and a certain area is selected as potential hazard area based on faults and fractures. The made fault limited factor map was used in GM-GPP to identify suitable area by avoiding fault risks. In this scale there are 42 faults and fractures in the study area (Figure.3).

Socioeconomical dataset

Socioeconomic study and conditions are usually hard to identify and investigate, as they are related to the human beings and their characteristics, which usually differ widely within the same community and from one community to another.

In the study area among the socioeconomic parameters, maybe population center, access road and land use can be considered in the GPP site selection project. Based on the land use data layer all around the study area is suitable for GPP construction. For this reason land use data layer did not appear in the model.

Population Center

The location and distribution of Villages, single buildings, agro nomads camping, sheep farming, stadium and sport centers, burial grounds, mosques and etc considered as population center data layer. To avoid of selection or affect these areas, 500 meter buffer size was given around these features to make the population center limited data layer. The clip tool in ArcInfo between the population center limited map and study area map was applied to make the suitable area based on the population centers or factor map which was used in the GM-GPP.

There are three small villages in the study area (Figure. 4). Valezir is located in the northern part and comprises about 50 families. Dizo is in the northwest of the area comprising about 30 families and the largest village is Moeil that is located in the southeast of the area with more than 400 families whose dominant occupation is sheep keeping and cultivation (Yousefi, 2004).

Access Road

One of the important parts of every socioeconomic study is the condition of road network in the project area. The location of roads can play a significant role in reducing costs and limiting environmental impacts during construction and utilization of GPP. Siting a GPP near existing road networks will minimize the creation of new roads during construction and for maintenance.

In the study area 16 km asphalt road provides access to the field from Meshkinshahr city to the village of Moeil, then continue to the geothermal site south of the village (Figure.4).

In the GPP site selection project 100 meter buffer size was given around the road features to make the restricted road map. By using clip tool in GIS, factor map without restricted area was made to employ in the siting model.

Technical dataset

Like all forms of electric generation, both renewable and non-renewable, geothermal power generation has some technical requirements. In this study the most important requirements including anomaly zone, production wells pad locations and hot springs categorized in to the technical dataset in GM-GPP model.

Anomaly zone

Geothermal fluids can be transported economically by pipeline on the earth's surface only a few tens of kilometers, and thus any generating or direct-use facility must be located at or near the geothermal anomaly zone.

Anomaly zone in the study area is around 7 km^2 (Figure.4). To find the GPP suitable area based on the anomaly zone in NW Sabalan 3km buffer size was given which it surrounded anomaly zone feature.
By the means of using clip tool in ArcMap only the buffer of anomaly zone around 75 km^2 selected as a factor map and suitable area for GPP siting model.

Wells locations

Until now there are 3 exploration and 2 injection wells at the study area (Figure.4). To avoid of selecting area so near to well pads 200 m buffer size was given to the wells features to make the restricted wells map.
The area without this limitation was selected to make the suitable area for GPP based on the wells location which was used as factor map in the siting GIS model.

Hot springs

Hot springs are evidence of a subsurface heat source and the temperature of springs has correlation with amount of heat flow. Those locations where hot springs rise to the surface are geothermal potential prospected areas because it is assumed that the probability of the occurrence of a geothermal resource is higher than that in the surrounding area.
There are 7 hot springs (Figure.4) including hottest in the country which is called Geynarjeh with 86°C located in the study area. With regard to the chemical and physical characteristics of the thermal waters, they have been traditionally used for recreational and balneological purposes in the form of swimming and bathing pools as a fundamental version of direct-heat utilization of geothermal energy in the region (Saffarzadeh and Noorollahi, 2005).
The clip tool was applied between the study area and limited hot springs map with 100 meter buffer size to make the hot spring factor map to use in the model.

DATA INTEGRATION METHOD

Boolean integration model which was used in the current study involves the logical combination of binary maps resulting from the application of conditional "AND" (Intersect) operator.
For performing Boolean logic model the study area based on each evidence layer was classified into two different areas. The area which assumed suitable area assigned the value of 1 and the others value of 0. Fig.2 shows the conceptual model of the Boolean integration method which was applied for data integration in the site selection process.
Physical suitability was determined by integrating the selected suitable area based on slope, hydrology (river) and faults factor map. This three evidence layers were overlain by Boolean "AND" operator and the selected areas were combined (union) to identify physical suitable areas.

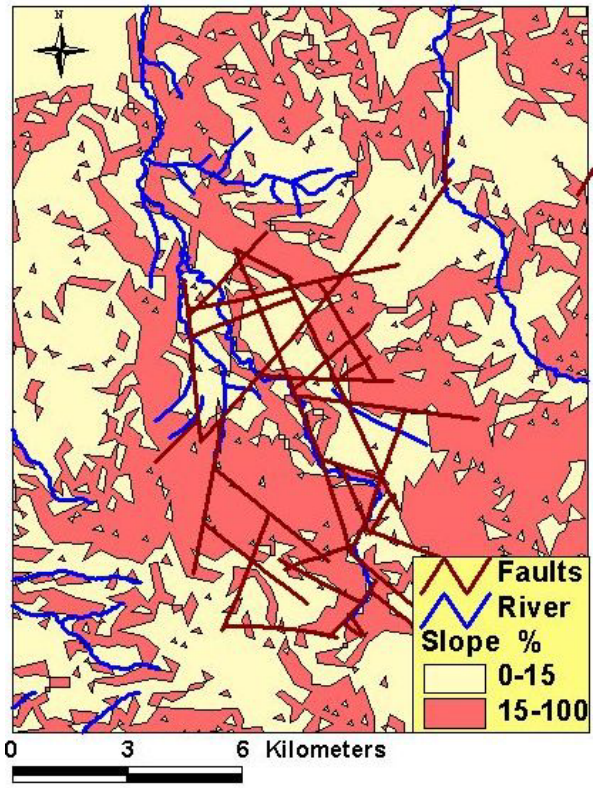

Figure.3. Physical evidence layers

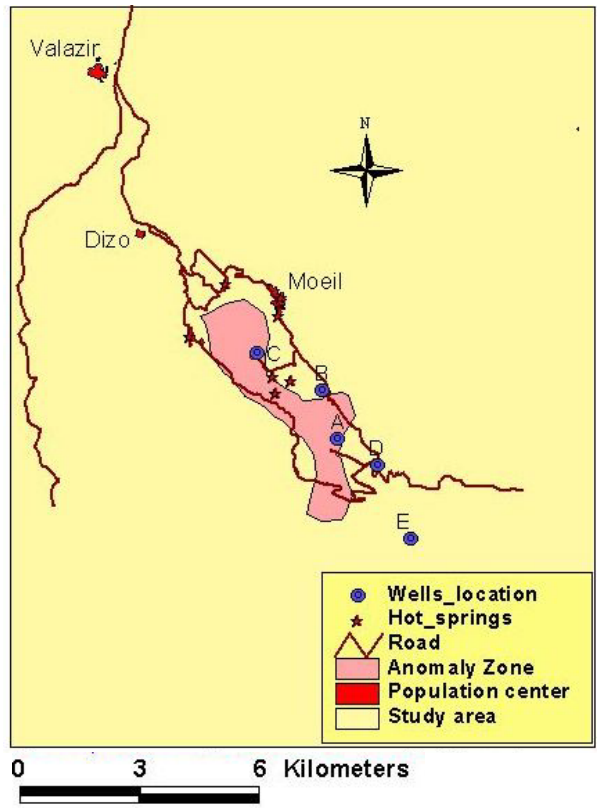

Figure.4. Socioeconomic &technical evidence layers

Socioeconomical suitability was identified by integrating selected areas on the base of population centers and access roads factor maps. These two layers were overlain and the selected areas were combined (union) to identify the socioeconomical suitable area.
Technical suitable area was determined by overlapping of the anomaly zone, well locations and hot springs factor maps by using the Boolean "AND" method. The selected areas were merged to identify the technical suitable area for GPP.
Table 1 shows the employed evidence layers and criteria which were used in geothermal Power plant site selection process.

Tabale.1.Iineigration criteria of evidence data layers

Data sets	Evidence layers	Non-suitable area
Physical	Slope	Slope >15 %
	River	Rivers with 200 m buffer
	Faults	Faults with 200 m buffer
Socio-economical	Population center	Population center with 500 m buffer
	Roads	Roads with 100 m buffer
Technical	Anomaly zone	Anomaly zone and out of 3000 m buffer around anomaly zone
	Wells locations	Wells with 200 m buffer
	Hot springs	Hot springs with 100 m buffer

Finally the Physical, Socioeconomical and Technical suitable area overlain and intersected using Boolean "AND" operator to identify the suitable geothermal power plant sites. Figure.5 shows the location and extend of 7 suitable sites.

CONCLUSION

In the current study the geothermal power generating site selection in NW Sabalan geothermal area were investigated and identified by using available physical data including slope, river and faults, socioeconomical data such as population centers, access roads and land use and technical data consisting anomaly zone, wells locations and hot springs. All of the involved digital maps provided in the 1: 25,000 scale with the precision of 10 meter.
Boolean integration method by using "AND" (Intersect) operators was applied to combine the evidence layers in GIS environment. Finally 7 suitable sites, around 1% of the study area were identified.
Table 2 shows suitable areas for constructing the geothermal power plant in the study area.
The designed model in GIS environment is a dynamic model and can be improve by adding new data layers or changing the criteria. Figure 6 shows the 3D map of the Sabalan geothermal field and selected Sites.

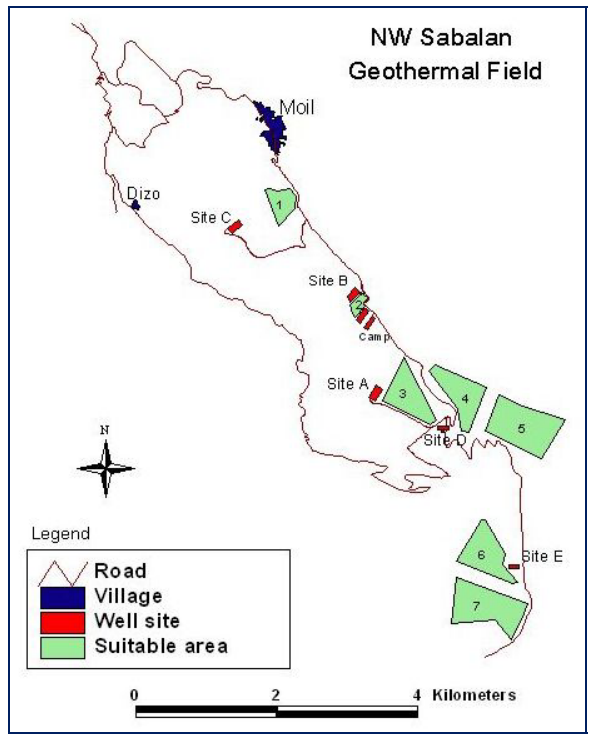

Figure.5. Defined sites for geothermal power plant installation

Tabale.2. Location and the area of defined suitable sites

Site	Location	Area (m^2)
1	East of site C	141000
2	South of site B	53000
3	Southeast of site A	312000
4	North of site D	323000
5	East of Site D	548000
6	West of site E	347000
7	South of site E	501000

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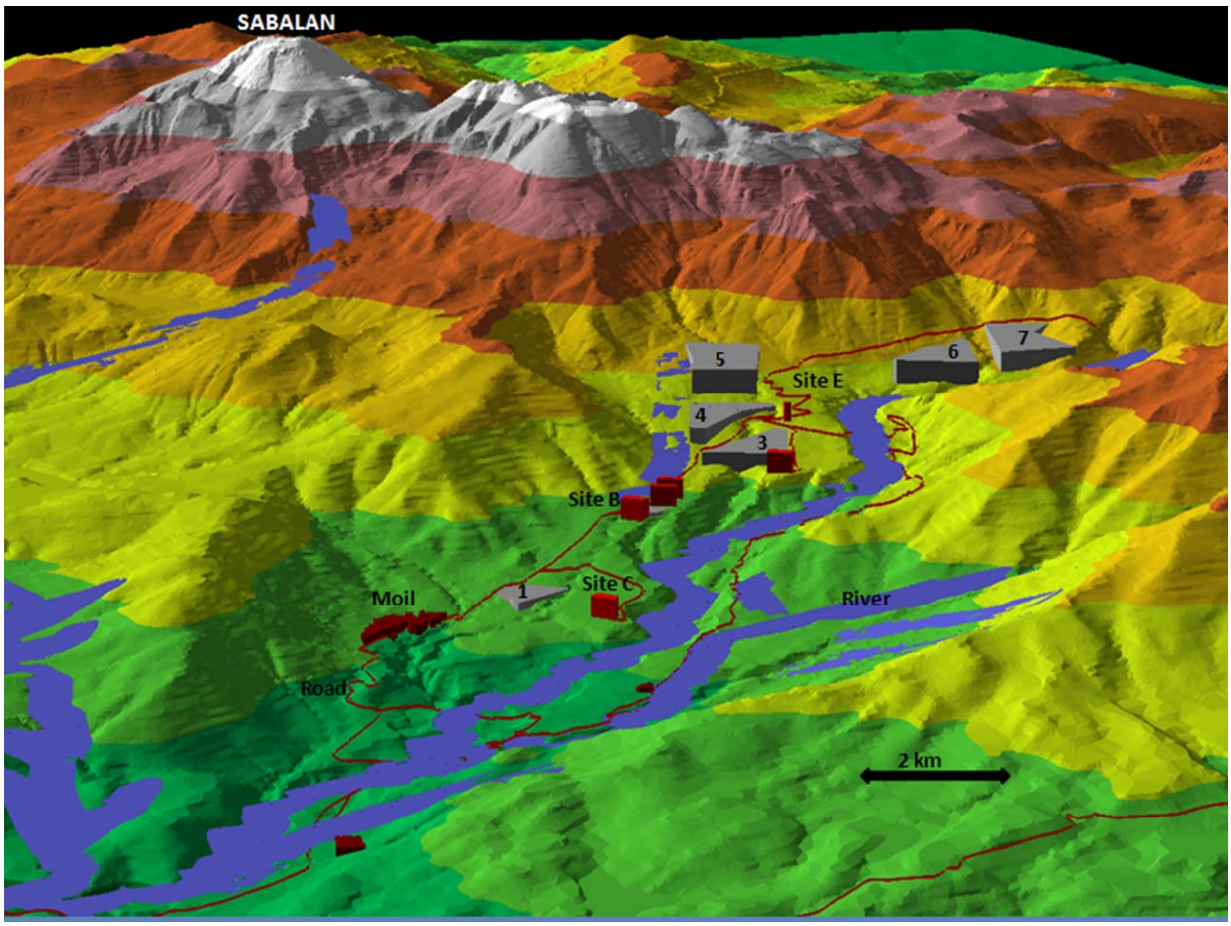

Figure.6. Sabalan geothermal field and defined sites for geothermal power plant installation